Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results

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LONG-TERM GOALS

The goal of this research is to develop greater understanding of the how the flocculation of fine-grained sediment responds to turbulent stresses and how this packaging of sediment affects optical and acoustical properties in the water column. Achieving these goals will improve the skill of sediment transport models and hence prediction of underwater visibility.

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OBJECTIVES

1. Quantify the effects of aggregation dynamics on the size distribution of particles in the bottom boundary layer;
2. Quantify how changes in particle packaging affect the optical and acoustical properties of the water column.
3. Develop models describing the associations between particle aggregation, stress, and the acoustical and optical fields.

APPROACH

The approach is to obtain measurements that permit comparisons of temporal evolution of bottom stress, suspended particle size, and optical and acoustical properties in the bottom boundary layer. We measure optical and acoustical properties of the water column by coupling an ac-9 (9 wavelength absorption and attenuation) and a two backscattering + CDOM fluorometer to the USGS tripod on their profiling arm (hence resolving the first 2m of the bottom boundary layer). Coupling the ac-9 with a switch and a filter, we are able to obtain calibration independent optical properties of particles (Slade et al., 2010) which provide us concentration, size and compositional information regarding the particles. In addition, it allows us to obtain the parameters needed to compute underwater visibility and provide the inputs necessary to Dr. N. Farr's group to model the optical field affecting underwater optical communication.

Collaborating with Dr. Hill, Sherwood and Trowbridge, our data will be used to develop and constrain a sediment concentration module that will be incorporated to the Community Sediment Transport Modeling System (CSTMS).

WORK COMPLETED

Work in 2011-2012 focused on two areas. First, we worked on publication of results from past field experiments. Second, we processed the data obtained in the field season in September and October of 2011 at the Martha's Vineyard Coastal Observatory where we integrated our instrument into the USGS tripod which resolves the bottom 2m of the bottom boundary layer. Processed data has been made public on the web in conjunction with the USGS data (http://pubs.usgs.gov/of/2012/1178/digdatafiles.html).

RESULTS

The data set collected at MVCO in the fall of 2011 using the USGS profiling system (Fig. 1) is unique in its ability to span the bottom 2m of the bottom boundary layer (BBL, Fig. 2) hence allowing us to further our understanding of particulate properties and their dynamics in the BBL. We observe strong gradients in time and space between different properties (e.g. Fig. 2 for optical transmission and acoustic backscattering). Each property measured allows us to compute a settling velocity by fitting a Rouse profile to the data (balancing turbulent resuspension, estimated from measured shear with settling), and provide settling estimate which are consistent with our understanding of what these parameter as sensitive to (Fig. 3).

With our OASIS support we continued to work on developing a theoretical understanding to the optical properties of aggregate particles (Stemmann and Boss, 2012) and analysis of the effect of size and packaging on acoustical backscattering (Russo and Boss., 2012, Russo et al., 2012). These studies suggest that current off-the-shelf ADV technology can provide realistic estimate of mass concentration but that packaging state of the particles have a great effect on backscattering and need to be taken into account for realistic estimates of particulate mass using acoustics.

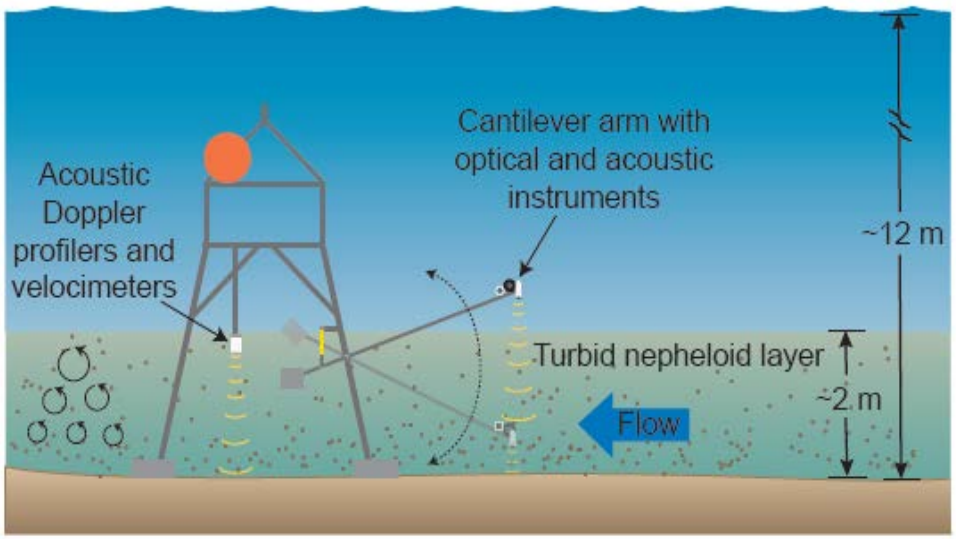

Figure 1. Conceptual illustration of the profiling tripod with instruments on a cantilever arm for profiling particle distributions in the bottom boundary layer. (Illustration by P. Dickhudt).

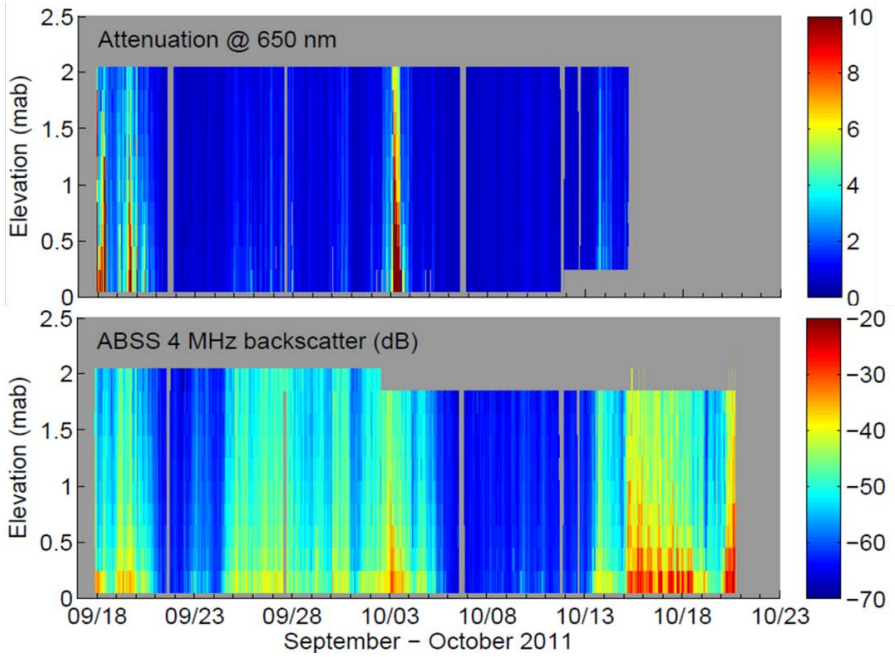

Figure 2. Time series of profiles of beam attenuation at 650 nm from the ac-9 (top panel, units are m^{-1}) and acoustic backscatter intensity at 4 MHz, measured 0.2 m from the transducer (units are decibels). Differences in the amplitude, duration, and vertical gradients in the response of the optical and acoustic proxies for suspended material are caused by changes in the concentration, size, composition and degree of aggregation of the particles in suspension.

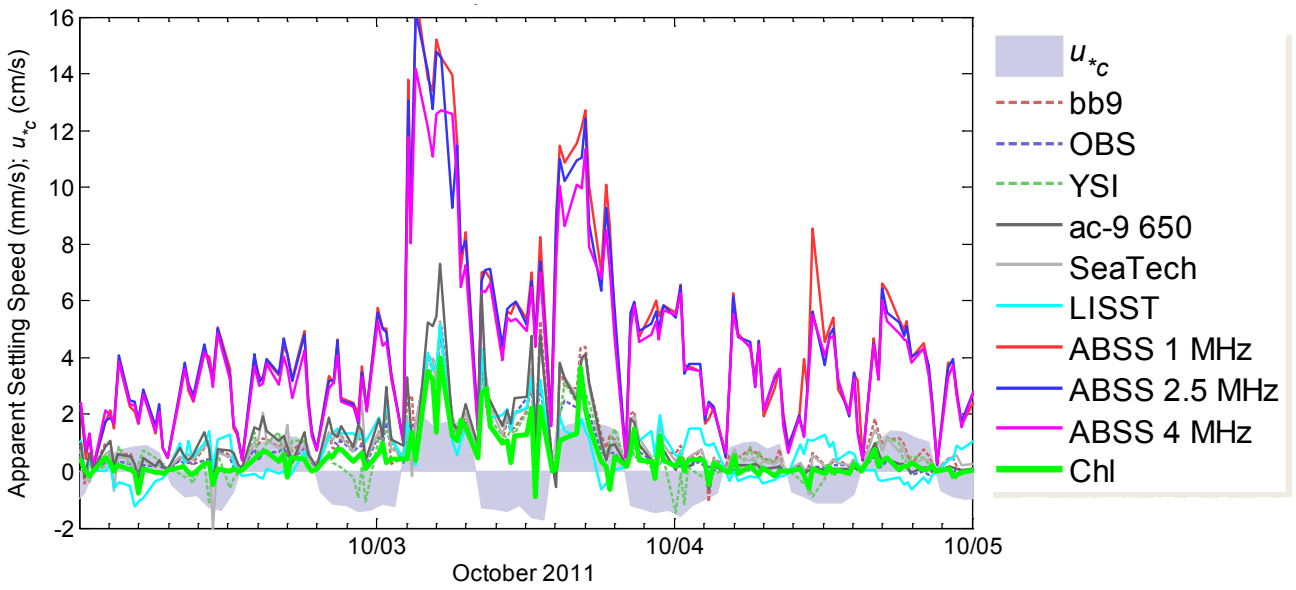

Figure 3. Time series of settling velocity inferred from different measurements by fitting a Rouse profile to them. Each parameter provide a different estimate as it is sensitive to different particles (e.g. ABSS acoustic is most sensitive to sand particles, LISST to aggregate, beam attenuation to particles smaller than 20μm and chlorophyll to phytoplanktion.

IMPACT/APPLICATIONS

The high-resolution time series of particle, optical, and acoustical properties provide us for the first time the possibility to constrain settling velocity of different particles in the BBL needed to understand clearing rates in the BBL. This is a crucial input to visibility models as well as those for sediment transport.

RELATED PROJECTS

Instruments used in this work have been purchased through a DURIP grant (N000141010776 to E. Boss)

Observations made as part of the RIVET DRI are similar to OASIS measurements. They will help to broaden our understanding of the links between particle, optical properties and their remote sensing signatures (N000141210106 to E. Boss, collaborating with P. Hill and T. Milligan).

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PUBLICATIONS

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